ence to politics was that the best politics was a good administration and that was what he expected of our department.

The 2,000-mile tentative additions to the state system, which were decided on in November, 1929, caused considerable comment, mostly favorable, but that action was just what caused the article referred to in the Chicago paper. This article referred to the addition as being 96 widely separated local roads.

Perhaps one of the best means of checking on the road system as a whole would be to take a railroad map of Indiana and a state road map and compare them. The two maps look much alike except that there are more railroads. The railroads were built for profit and service consequent thereto. The highways are built for service and it is logical that the network should resemble that of the railroads.

There has been great advancement in road building and the uses of roads during the past twenty years and, with the many experts working on the problems connected therewith, we may expect some revolutionary developments within the next like period.

PROTECTION AGAINST STREAM EROSION

By John L. Stewart, Franklin County Engineer

Erosion has caused, up to the present time, more than $10,000,000 worth of damage to the farm land in the United States, and the earth, stone, gravel, etc., from this erosion being deposited on other land has caused more than $3,000,000 worth of damages. The U. S. Department of Agriculture is now carrying on actual work throughout the United States to stop erosion and damage to farm land. The method most commonly employed is the benching method. No figures are available at this time as to the amount of damage caused to roads and bridges by erosion, but I am sure it would run well into the millions. The Department publishes a bulletin which deals with the selection of bridge sites in reference to erosion.

Before going into the matter of protection against stream erosion, let us consider some of the causes for stream erosion and the conditions which now exist along the streams. The natural tendency of water is to flow in a fairly straight line. The stream could easily be made to flow on long easy curves if sufficient waterway were given to the stream and if it were not obstructed by drift, growing trees, or many other things which tend to deflect the current from its natural course. It is a known fact that one stone containing less than one cubic foot has changed the course of a large stream, and that the sand shifting against a small fishing boat on the bottom of Lake Michigan is the cause of the formation of a part of Chicago's lake front.

Unfortunately for us, many of our roads were laid out or constructed along the banks of small streams and rivers in the early history of our state. This was due, of course, to lack of funds and modern machinery to construct grades equal to those already available along the streams without any great expenditure of money. Now that these roads are located as they are, it is necessary to protect the banks to keep them from washing the road and otherwise rendering it unfit for traffic. Wherever it is possible and can be done without excessive damage to adjoining property, the most economical solution is to move the road to a safe location away from the stream. However, in a large number of cases, it is not possible to do this, as villages and towns have already been built along the highway and to do so would inconvenience those whom the road was intended to serve.

Various Types of Protection

Since it would consume too much time to discuss all the types and uses of the various protections, I shall deal only with those used to protect roads and bridges with which the highway engineer has to deal.

A great number of different types of protection are now in general use in this country. One of them is the **retard method.** This method is very practical and economical because of the fact that the stream is made to deposit earth and silt at the proper location. These retards are usually constructed of steel posts covered with wire mesh in fence fashion, set at right angles to the bank to be protected, and securely anchored by wire cables. The downstream side is then well banked with brush, and trees are anchored to the retard to catch the silt.

Concrete mattresses constructed by fastening together slabs of concrete making a flexible mat were used by the Miami

Conservancy District in protection of river banks on their flood control work in the Miami River valley in Ohio. This type of protection deserves worthy mention but is somewhat expensive to construct.

Stone mattresses constructed by the use of a layer of stone 12 inches to 18 inches thick between two layers of wire mesh securely fastened together at intervals not exceeding 3 feet to 4 feet are a very desirable type of flexible protection. They tend to catch silt and are economical to construct where local stone is available.

Pile dikes are very effective for the training of a stream and the prevention of erosion.

Stone baskets, well constructed, are an excellent substitute for piles where the conditions are such that piles cannot be driven.

Bridge Failures

We are many times asked the question, "What is the cause of most of the failures in bridges?" I think I can safely say that 90% of the structures which I have had to rebuild have failed in the substructure because of erosion in the stream bed.

Many of the older types of bridges were built with shallow foundations carried down in many cases not more than 1 or 2 feet below the stream bed. Many of these bridges must be protected if we expect them to continue in service. Probably the most economical and permanent type of protection in this case is to drive a row of interlocking steel sheet piling between the portion to be protected and the stream. The cavity between the piles and abutment or wing is then filled with concrete. This method is not practical in many cases, however, as there is not always sufficient head room under the bridge to permit the use of pile driving machinery.

When steel sheet piles cannot be used for protection, the next best solution is the concrete curtain wall. It may be designed from the same formulae as used for ordinary plain or reinforced concrete walls but must be carried down to a sufficient depth below the stream bed to make sure that it is well below future erosion. The cost of the sheet piles which we used last year on Big Cedar Creek protection in Franklin County was $1.00 per lineal foot, the piles being 14 feet in length and approximately 12 inches in width. The cost included driving. Concrete used to fill the space between the piles and the concrete wall cost $12.00 per cubic yard in place.

Examples of Stream Control

The following method was used in protection of the east bank of Johnson's Fork Creek in Franklin County, along which one of the more important county roads was located. Complete plans and specifications were ordered for the protection of the creek bank, including the rebuilding of the road where it had been washed away completely or in part, and an appropriation was made by the county council. The first step of the engineer was to change the alignment and lay the road back as far as possible from the stream and to replace the short abrupt turns with long easy curves. Soundings were taken in the stream bed at proper locations as determined by cross sections so as to give room for the protection including the proper slope to the roadway. It was found that certain portions of the stream bed could be penetrated with piling to a depth of 10 feet while at other locations apparently solid stone ledges were protruding from the surface. It was then decided to use creosoted cypress piling where they could be driven on the side of the protection next to the stream as shown in Fig. 1.

Fig. 1. Wire and timber pile riprapping.

These piles were ordered 14 feet long, 8 inches in diameter at the small end, and treated with 12 pounds of creosote per cubic foot. The piles were driven to a depth of 10 feet with the 4 feet remaining above the stream bed to serve as protection. The piles were driven on a line parallel to the center line of the road. A pile cap which would give most protection to the piles was used. A portable driver with swing leads was chosen for the job. This permitted us to move easily and quickly and to keep all of the machinery at the top of the bank and out of the way of the stream. When the piles were driven, two layers of galvanized wire mesh were securely fastened to the back of the piles with long iron staples to retain the stone riprap. This wire mesh was composed of No. 9 wire 6 inches center to center, both ways, and the wire was covered with a 2-ounce coating of spelter. The next step was to lay up a dry stone wall just back of the piles and wire mesh. This wall was constructed of one-man stone, 2 feet thick, laid up within 18 inches of the tops of the piles, leaving space to take care of the stone mats to be placed on the slopes.

The cost of these piles, 14 feet in length, including driving, was 90c per foot, and the cost of the stone retaining wall was $2.00 per cubic yard of stone used. The galvanized wire mesh, 55 inches wide, cost 17c per lineal foot.

After the work described had been completed, the banks were cut or filled to a slope of 1½:1 to receive the stone mats. The loose earth fills were then compacted as much as possible with hand tamps and the entire surface was covered with two layers of galvanized wire mesh (the same as used before) securely wired together to form the bottom of the mat. Tie wires were then placed at 4 feet intervals in both directions and made sufficiently long to extend up through the stone mat so that the wire mesh at the top and bottom of the stone mat could be fastened together. The stone composing the mat was then placed either in shingle or paved fashion to a depth of 18 inches. The two top layers of wire mesh were then placed and securely fastened with the tie wires previously placed. The cost of the stone mat was $1.60 per square yard.

Stone basket protection (see Figure 2) was used where the stream bed consisted of ledge rock and where piles could not be driven. The stone baskets answer the purpose of both the piles and the stone retaining wall. The stone baskets were formed by two layers of woven wire mesh made circular in shape and 5 feet in diameter. The bottoms of the baskets were sloped so that they would tilt about one foot in the total height of 55 inches. The baskets were completely filled with hand-laid, one-man stone. One single layer of wire mesh formed the top and bottom of several baskets and was securely fastened.

The method of constructing stone mats, sloping of bank, etc., were the same as specified in the protection where the creosoted piles were used.

Fig. 2. Wire basket bank protection.

More adequate laws should be placed upon our statute books providing for the maintenance of streams, such as the changing of the channel, the removal or planting of trees, and the construction of adequate protection wherever roads or bridges are affected or where the stream forms the boundary line between land owners. This would be the economical solution of the problem, and but few of the large and more expensive forms of protection would be necessary.

In constructing new bridges, much consideration should be given to the subfoundation. If the structure is of any size, and even though the strata which are to be penetrated show sufficient bearing values to withstand the weight of the structure, piles should be driven at least on the stream side of the abutment and wings constructed where erosion is liable to occur. On small bridges the more economical solution is to resort to invert paving with secondary walls at either end of the invert, carried down to the bottom of the abutment foundations.

There is no magic or mystic formula which can bring about the control of a stream. Such control can only be accomplished through the application of tried and practical methods, based on sound and scientifically correct principles, under the direction of experienced engineers. Whether to design a mattress, retard, jetty, or other structure for any particular place depends on the condition at that particular place.

LOOKING BOTH WAYS

By the Hon. Horatio S. Earle, Ex-State Highway Commissioner, Detroit, Michigan

The wheel was the greatest invention of human ingenuity, for without wheels there could be no wheelbarrow, ox cart, gig, wagon, automobile, locomotive, boat, or engine. The universe is composed of wheels and it is said that many men have wheels in their heads. We are not here, however, to discuss wheels, but what they run on.

Roads as they were will not do, and roads as they are will not answer, but roads as they must be will function satisfactorily if properly made. Roads as they were when I was a boy were passable some months in the year at from five to ten miles an hour. It was a day's work for a team of horses to pull a load of wood or farm produce to market ten miles away.

To the old saying "Give the Devil his due" it is only fair to add an amendment, "And the farmers, too," for they gave the land for the right-of-way and made these roads. It was a herculean task with the equipment available at that time. I can remember how, after the crops were in, the citizens were called out to work out their road taxes. They always put the roads into such shape that for weeks they were not passable with any degree of comfort, because they would plow alongside the road and then scrape the wornout earth and sod into the road. On the steep grades they would make "water-bars" across the road a foot high that would throw you out of a buggy if you went over them at five miles an hour. My father and his boys worked out these taxes, but father had a brother who thought he was sickly and he would take a hoe to lean on and would "stand out" the taxes. This